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REMOVING SMUT BALLS FROM SEED WHEAT[1]

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IMPORTANCE OF SMUT-FREE SEED

Stinking smut in wheat results either from sowing smutty seed or from sowing seed in smut-infested soil. The ability of the smut spores to survive in the soil long enough to infect the next crop depends largely on conditions of soil temperature, soil moisture, and farming practices. Soil infestation is a serious factor in smut infection only in limited areas in the United States, chiefly in the Pacific Northwest. In these areas seed treatment is not fully effective in controlling the disease.

Where soil infestation does not occur, stinking smut may be prevented in large degree by treating the seed with formaldehyde, copper carbonate, or other fungicides which kill the smut spores adhering to the seed. However, these materials will not kill the spores in unbroken smut balls remaining with the seed, and therefore to obtain complete control these smut balls should be removed before treating, otherwise in the subsequent handling of the seed incidental to sacking, hauling, or sowing they may be shattered and the treated seed thus may be reinfested.

Considerable work has been done by commercial, State, and Federal agencies in developing seed-cleaning equipment and methods for removing dockage materials from grain in order to increase its market value.[2] However, little effort has been made to determine the effectiveness of such equipment and methods in removing smut balls from wheat. Therefore, a study was made of the possibilities of a number of grain-cleaning devices in this direction.

[1] For assistance in conducting the tests herein reported and analyzing grain samples, the authors wish to thank the following: L. G. Schoenleber, Division of Mechanical Equipment, Bureau of Agricultural Engineering; R. H. Black and Harold Anderson, Grain Division, Bureau of Agricultural Economics; E. R. Ausemus and O. A. Vogel, Division of Cereal Crops and Diseases, Bureau of Plant Industry; and A. J. Schwantes, Agricultural Engineering Department, University of Minnesota.

[2] Black, R. H., and Boerner, E. G. cleaning grain on farms and in country elevators. U. S. Dept. Agr. Farmers' Bull. 1542, 27 pp., illus. 1927.

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PHYSICAL CHARACTERISTICS OF SMUT BALLS

Smut balls separated from one lot of soft red winter wheat by hand and weighed were found to be approximately 29 percent as heavy as sound kernels of wheat. The smut balls averaged 0.0963 gram per 10-smut-ball lots and the wheat kernels 0.3320 gram per 10-kernel lots. Variations in the weight of smut balls were greater, however, than those of the wheat kernels. The maximum weight of 10 smut balls was 0.1321 gram and the minimum 0.0763 gram, based on weights of twenty 10-smut-ball lots. With sound kernels of wheat of the sample used, the weight of 10-kernel lots ranged from 0.3063 to 0.3637 gram.

Smut balls removed from one lot of Purplestraw wheat were found to weigh on an average approximately 25 percent as much as the kernels of wheat. The smut balls averaged 0.0795 gram per 10-smut-ball lot and the wheat kernels 0.3090 gram per 10-kernel lot. The weight of individual smut balls ranged from approximately 0.0004 to 0.0205 gram and the sound kernels of wheat from 0.0222 to 0.0381 gram. The Purplestraw wheat was screened before weighing and only those kernels which were retained on an eight-mesh screen were used.

The extreme difference in weight of smut balls and sound kernels of wheat in both lots may have been due in part to the low moisture content of the material. The wheat containing the smut balls had been exposed to room conditions in a laboratory for several months before the weights were made. Smut balls from different varieties of wheat also differ as to physical characteristics.

No measurements of dimensions of smut balls and kernels of wheat were made, but observations indicate that smut balls differ considerably in size and shape with different physiologic forms of smut and different varieties of wheat. Some are much smaller than the kernels of wheat from which they are selected, and others may be as large or even larger than the wheat kernels. A difference in weight and size between smut balls and wheat kernels was indicated in experiments with machines using screens and air blast for cleaning. Results of tests made with such cleaners show that some smut balls may be screened out and a large percentage, if not all, removed by air blast.

FARM GRAIN CLEANERS

Mechanical separation of such materials as wheat kernels, smut balls, weed seed, and chaff is usually effected in grain cleaners by utilizing differences in (1) size of particles, (2) shape of particles, (3) specific gravity of particles, (4) character of surface of particles, and (5) hardness of particles. Farm grain cleaners usually embody the principle of separation by size, shape, and specific gravity. When screens and air blast are used, the machines are generally known as fanning mills, which is the type most commonly found on farms.

In the pocket-type cleaners, vertical disks, indented cylinders, or indented belts are usually employed. Figure 1 illustrates what is generally known as a disk machine, and figure 2 an indented-cylinder cleaner, known in some sections as a cockle machine. These machines separate according to size or shape of particles only, unless equipped with a fan which removes the light material. In the spiral gravity separator (fig. 3) the seeds pass downward over a curved

surface and, as the round weed seeds move at a more rapid rate than the kernels of wheat, they are carried outward into a stream near the outer edge of the spiral by centrifugal force.

The fanning mill depends on screen agitation and wind blast for separation. Grain passes through the hopper down to one or more scalping screens, where the larger material is screened off. The seeds that fall through the scalping unit are subjected to a blast of air and to further screen separation in the process of cleaning. In some machines of this type final screen separation precedes the air blast. Both end-shake and side-shake screen agitation are used, in different machines, and the lower screen may be either flat or cylindrical. All cleaners of this general type embody the principles involved in separation (1) by size or shape, and (2) by specific gravity.

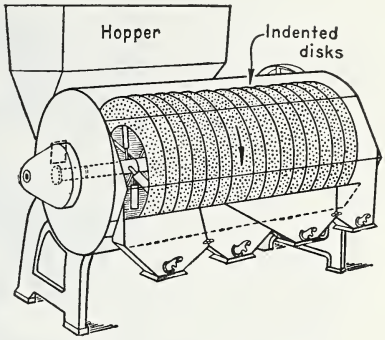

FIGURE 1.—Disk-type seed cleaner.

Figure 4 illustrates an end-shake cleaner with horizontal wind tunnel; figure 5, a side-shake cleaner with fan; and figure 6 an end-shake cleaner with vertical wind tunnel. All three are of the fanning-mill type. These machines are similar in principle and differ only in details of design and construction.

PRELIMINARY EXPERIMENTS

To determine the suitability of farm-sized grain cleaners for removing smut balls from wheat, test runs with grain cleaners of several

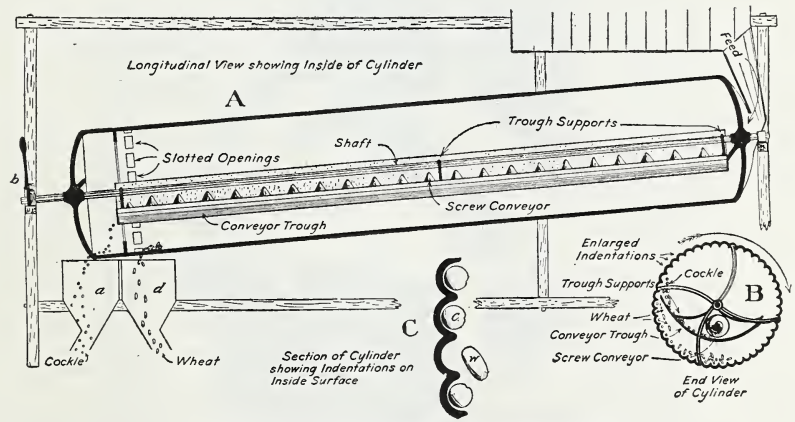

FIGURE 2.—Indented-cylinder, or cockle seed cleaner.

types were made cooperatively by the Bureaus of Agricultural Engineering, Plant Industry, and Agricultural Economics.[3] Machines typical of those commonly used on farms were selected, although

[3] These preliminary tests were conducted by E. G. Schoenleber, Bureau of Agricultural Engineering; E. R. Ausemus, Bureau of Plant Industry, and R. H. Black, Bureau of Agricultural Economics, in cooperation with the Minnesota Agricultural Experiment Station.

several other machines approaching the commercial cleaner type were included. Power required for operation and initial cost limit the use of the latter type for farm purposes. The presence of a factory repre-

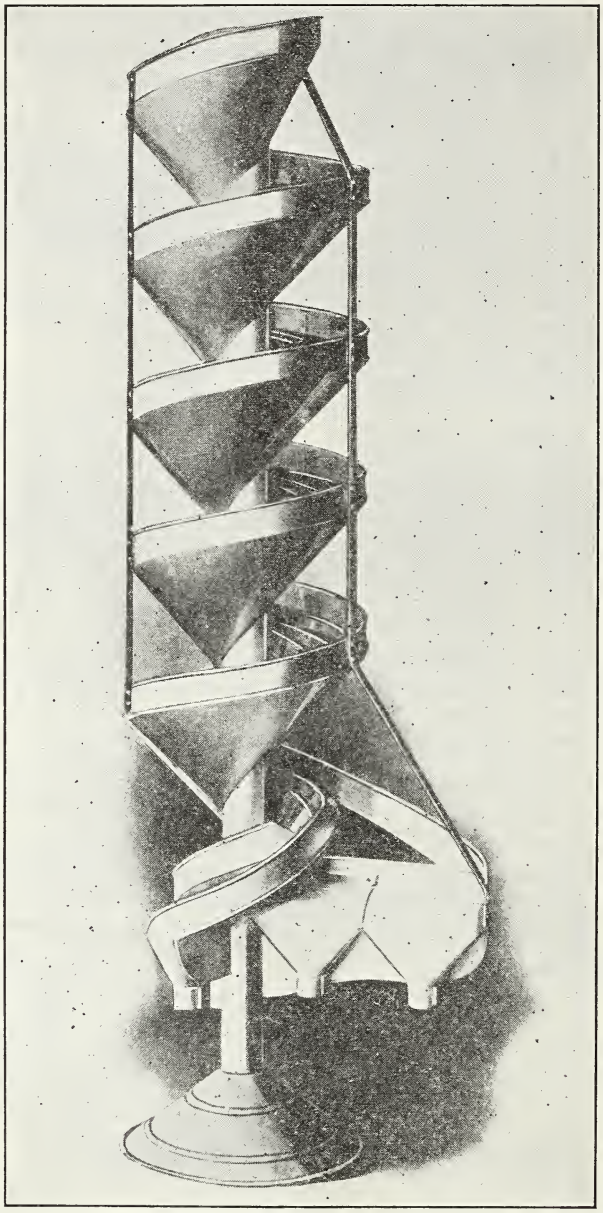

FIGURE 3.—Spiral gravity seed cleaner.

sentative of the respective cleaners for the duration of the test runs was encouraged, and in the absence of a representative the machine was operated according to factory specifications.

METHOD OF PROCEDURE

No previous study having been made by the Department of Agriculture of grain cleaners for use in removing smut balls from wheat, it was first necessary to establish their effectiveness under normal operation. Obviously, a machine for removing smut balls from wheat to be practicable must also remove foreign material.

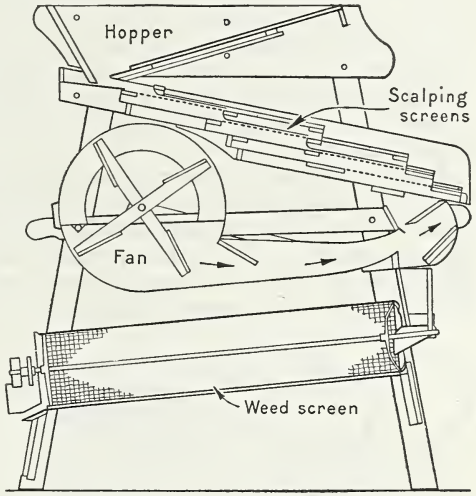

FIGURE 4.—Fanning mill with end-shake scalping screens and revolving weed screen.

Three varieties of wheat were selected for the test runs, namely, a mixed wheat containing an average of 143 smut balls per 500-gram sample, a red durum wheat containing 45, and a northern spring wheat containing 23 smut balls per 500-gram sample. Physical analysis and smut-ball counts were made from composite samples of the uncleaned grain used in each test run. These were made up from samples taken at intervals during the run. A similar sample was taken from the cleaned wheat for physical analysis and smut-ball counts. Comparison of the number of smut balls in the samples before and after cleaning thus established the effectiveness of the machine for removing smut balls.

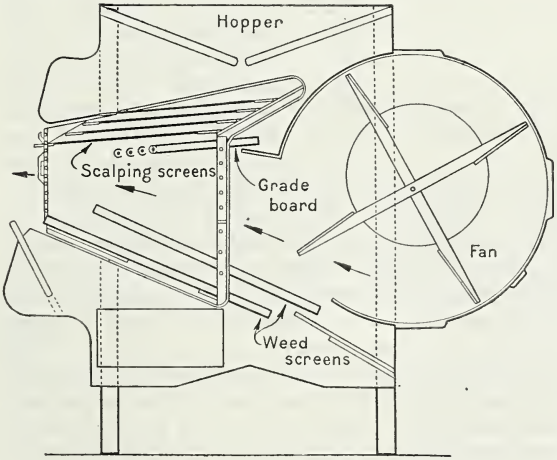

FIGURE 5.—Fanning mill with side-shake screens.

Duplicate test runs were made for each of the three varieties of wheat on each machine. The quantity of wheat used per run ranged from 1 to 10 bushels according to the capacity of the machine. The rate of cleaning, expressed in bushels per hour, was recorded as was also the power requirement for each run. All material from each grain stream was caught in a separate container, weighed, and examined.

EFFECTIVENESS OF CLEANERS

Table 1 is a summary of the results of the preliminary tests, the different machines being identified by number and by method of separation. Owing to marked variation in smut infestation of the

different kinds of wheat used, the data are presented by variety of wheat.

The performance of each machine as shown in table 1 is the average of duplicate runs. Results of individual tests showed a wider variation in the effectiveness of the machines than is indicated in the table, owing, in large measure, to the uneven distribution of smut balls in each variety of wheat and to the method of sampling. Smut-ball counts made of samples of wheat taken before cleaning showed a variation of from 57 to 480 smut balls per 500 grams for the mixed wheat; 21 to 70 for the red durum; and 12 to 31 for the northern spring wheat.

In test runs with the various machines an average of two-thirds of the smut balls in the uncleaned wheat was removed in the cleaning process. In mixed wheat the removal was 75 percent, in durum 67 percent, and in the northern spring 58 percent. Although part of this difference may be due to variety influence, close correlation of the data should not be attempted in view of the variation in the infestation in different varieties and lots of wheat used and the uneven distribution of smut balls in the wheat.

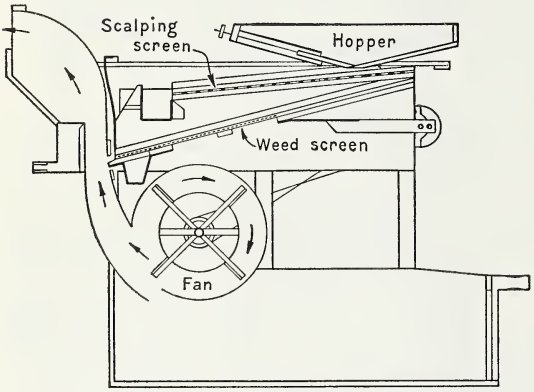

FIGURE 6.—Fanning mill with end-shake screens and vertical wind tunnel.

The removal of smut balls by individual machines varied from 13 to 96 percent with mixed wheat, 23 to 94 percent with red durum, and 15 to 81 percent with northern spring. Machines of the fanning-mill type removed an average of approximately 89 percent of the smut balls from the mixed wheat, 76 percent from the red durum, and 64 percent from the northern spring. Despite the variation in the number of smut balls in the different varieties of wheat before cleaning, there was, with one exception, only a slight difference in the number of smut balls remaining in the wheat after cleaning in the fanning mills.

In cleaning seed wheat in advance of treating it for the prevention of stinking smut, it is important to remove all of the smut balls. This should be accomplished, however, without too large a loss of good seed. Considerable differences were found in the machines tested in the percentages of cleaned wheat obtained. Those that gave large percentages of cleaned wheat frequently removed only a small percentage of the smut balls.

These tests were made with dry seed wheat containing very little foreign material and were concerned primarily with the problem of smut-ball removal. While the tests showed that cleaners of the fanning-mill type were more effective than other types in removing smut balls, this should not be construed as implying any recommendation as to types of cleaners for other purposes.

The results of these tests, in which the cleaners were operated in accordance with the manufacturers' instructions, show that a considerable portion of smut balls in wheat may be removed in one cleaning operation but that 100-percent removal should not be expected with this type of equipment as it is usually operated.

ADJUSTMENTS AND ALTERATIONS OF FANNING MILLS

Fanning mills are designed for use in cleaning a wide variety of cereal grains and other seeds having different physical characteristics for which adjustments and special attachments are provided. To test all possible combinations of adjustments and methods of operation would require more time and facilities than were available for this study; but the effects of variations in air velocity, screen size, and rate of feed on the performance of several cleaners in removing smut balls from wheat were studied. These tests were made with fanning mills only, because, as already stated, the preliminary tests showed this type of cleaner to be the most effective for removing smut balls.

Soft red winter wheat was used exclusively in these tests. This lot of wheat was much more heavily infested with smut balls than any variety used in the preliminary tests.

Test procedure with these cleaners was substantially the same as in the previous test runs. Approximately 2 bushels of the lot were run through a Boerner grain sampler, which mixed and at the same time cut the lot into two equal parts. During this process intermittent sampling from each of the two wheat streams was carried on, the composite sample being used for physical analysis and for smut-ball count. Test runs were made in duplicate, 1 bushel of wheat being used in each run. During each test run samples were taken intermittently from the cleaned-wheat stream, and these made up a composite sample from which physical analysis and smut-ball count were made. After running the individual test lot through the machine, the cleaned wheat obtained was run through two more times. During each run samples were taken for smut-ball counts and physical analysis and the grain from each wheat stream caught in a separate container for inspection.

In preliminary tests with machines nos. 11, 12, and 13 (types illustrated in figures 4, 5, and 6, respectively), it was found difficult to obtain a uniform rate of feed of grain from the hopper to the scalping screens. Changes were therefore made in the feeding mechanism on each machine to facilitate more accurate control. Such changes involved means of maintaining a uniform throat width and positive feed.

The rate of feed and the size of openings in the lower screen both affected the performance of machine no. 11 in removing smut balls, as is shown in table 2. As the rate of feeding the machine was increased the efficiency decreased, and as the size of opening in the bottom screen was increased the effectiveness in removing smut balls increased. With machine no. 11 much better results were obtained when it was operated at approximately 11 bushels per hour for all screen sizes used than at either of the higher rates of feeding. Results with the 2 by 10 mesh lower screen were better for the first cleaning for all rates of feeding than when either the 2 by 11 mesh or the 9 by 9 mesh screen was used.

TABLE 1.—*Effectiveness of 10 grain cleaners in removing smut balls and dockage from mixed, red durum, and northern spring wheat*

MIXED

Machine			Wheat									
			Before cleaning				After cleaning					
No. and type	Capacity per hour	Power required	Test weight per bushel	Dockage	Foreign material other than dockage	Smut balls per 500 grams	Test weight per bushel	Dockage	Foreign material other than dockage	Smut balls		Cleaned grain
										Per 500 grams	Removed	
	Bushels	*Horsepower*	*Pounds*	*Percent*	*Percent*	*Number*	*Pounds*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*
1. End-shake screen and fan	27.0	0.32	56.5	0.6	0.3	97	57.0	0.4	0.1	10	90	85
2. End-shake screen and fan	16.8	.28	55.5	1.0	.4	298	56.6	.9	.2	66	78	87
3. End-shake screen and fan	23.2	.27	56.3	0.8	.2	98	56.7	.1	.2	7	93	92
5. End-shake screen, fan, and reels	25.3	.34	56.6	.3	.2	69	57.0	.2	.2	10	86	87
6. Side-shake screen and fan	49.2	.29	56.1	.8	.4	162	56.9	.8	.1	7	96	77
7. Disk	25.6	.78	56.3	.9	.2	115	56.7	.1	.2	49	57	96
8. Cylinder and fan	44.4	1.30	56.1	.8	.3	164	56.4	.2	.2	51	69	97
9. Cylinder and fan	35.1	1.04	56.1	.4	.4	150	56.2	.1	.5	17	89	47
10. Riddle and screen	4.9	0.23	56.0	.9	.5	133	56.1	.2	.4	116	13	99
Average			56.2	.72	.32	143	56.6	.33	.23	37	75	

RED DURUM

1. End-shake screen and fan	29.7	0.31	57.1	1.8	0.3	49	57.7	0.2	0.2	12	76	86
2. End-shake screen and fan	12.2	.27	57.5	1.3	.4	26	57.9	.1	.1	12	54	90
3. End-shake screen and fan	17.0	.26	57.2	1.4	.3	38	57.6	.2	.1	9	76	91
5. End-shake screen, fan, and reels	26.5	.32	57.1	1.7	.3	61	57.8	.3	.2	10	84	86
6. Side-shake screen and fan	48.4	.29	57.3	1.0	.5	39	57.9	.1	.1	4	90	82
7. Disk	24.7	.79	57.2	1.3	.4	45	57.3	.4	.2	23	49	95
8. Cylinder and fan	45.1	1.34	57.3	1.0	.3	44	57.5	.2	.1	20	55	96
9. Cylinder and fan	31.0	1.29	57.0	.7	.5	65	57.4	.5	.6	4	94	55
10. Riddle and screen	5.7	0.21	57.3	1.2	.4	35	57.3	.9	.3	27	23	94
Average			57.2	1.3	.38	45	57.6	.32	.21	13	67	

NORTHERN SPRING

1. End-shake screen and fan	36.9	0.31	57.7	5.8	1.0	26	58.4	0.2	0.3	11	58	81
2. End-shake screen and fan	16.0	.29	57.8	5.0	0.8	26	58.7	.2	.4	8	69	84
3. End-shake screen and fan	16.9	.26	57.7	5.5	1.0	20	58.0	1.5	.4	8	60	87
4. End-shake screen and fan	31.5	.28	57.8	5.6	0.7	19	58.2	0.5	.5	10	47	87
5. End-shake screen, fan, and reels	27.2	.33	57.9	5.2	.7	20	58.3	1.3	.2	6	70	85
6. Side-shake screen and fan	108.6	.31	58.0	5.2	.8	20	58.4	0.8	.1	4	80	72
7. Disk	18.9	.78	57.9	5.1	.6	25	58.2	.5	.4	15	40	92
8. Cylinder and fan	47.8	1.27	57.9	5.3	.8	21	58.2	.2	.5	8	62	92
9. Cylinder and fan	27.8	1.25	57.8	5.0	.5	26	57.8	.4	.7	5	81	47
10. Riddle and screen	4.0	0.22	57.8	4.8	.7	27	58.0	.8	.6	23	15	96
Average			57.8	5.3	.76	23	58.2	.64	.41	10	58	

TABLE 2.—*Removal of smut balls and dockage from soft red winter wheat as affected by machine adjustments*

MACHINE NO. 11—5 TOP AND 4 BOTTOM SCREENS

Test no.	Machine: Speed: Shaker	Machine: Speed: Fan	Machine: Screens: Top: Size of openings	Machine: Screens: Top: Angle with horizontal	Machine: Screens: Bottom: Size of openings	Machine: Screens: Bottom: Angle with horizontal	Machine: Capacity: First cleaning: Per hour	Machine: Capacity: First cleaning: Cleaned wheat	Machine: Capacity: Second cleaning: Per hour	Machine: Capacity: Second cleaning: Cleaned wheat	Machine: Capacity: Third cleaning: Per hour	Machine: Capacity: Third cleaning: Cleaned wheat	Wheat: Before cleaning: Smut balls per 500 grams	Wheat: Before cleaning: Test weight per bushel	Wheat: Before cleaning: Dockage	Wheat: Before cleaning: Foreign material other than dockage	Wheat: After first cleaning: Smut balls: Per 500 grams	Wheat: After first cleaning: Smut balls: Removed	Wheat: After first cleaning: Test weight per bushel	Wheat: After first cleaning: Dockage	Wheat: After first cleaning: Foreign material other than dockage	Wheat: After second cleaning: Smut balls: Per 500 grams	Wheat: After second cleaning: Smut balls: Removed	Wheat: After second cleaning: Test weight per bushel	Wheat: After second cleaning: Dockage	Wheat: After second cleaning: Foreign material other than dockage	Wheat: After third cleaning: Smut balls: Per 500 grams	Wheat: After third cleaning: Smut balls: Removed	Wheat: After third cleaning: Test weight per bushel	Wheat: After third cleaning: Dockage	Wheat: After third cleaning: Foreign material other than dockage
	R. p. m.	*R. p. m.*	*In.*	8	*In.*	8	*Bu.*	*Pct.*	*Bu.*	*Pct.*	*Bu.*	*Pct.*	*No.*	*Lb.*	*Pct.*	*Pct.*	*No.*	*Pct.*	*Lb.*	*Pct.*	*Pct.*	*No.*	*Pct.*	*Lb.*	*Pct.*	*Pct.*	*No.*	*Pct.*	*Lb.*	*Pct.*	*Pct.*
1	316	316	1 of 14/16 and 4 of 12/16.	11	2 by 10 mesh	10	11	81	12	68	12	56	212	56.5	0.6	0.4	6	97.2	57.4	T.	T.	3	98.6	57.6	T.	T.	1	99.5	57.6	T.	T.
2	314	314		21			21	82	24	69	22	58	196	56.5	.8	.7	12	93.9	57.4	T.	T.	4	98.0	57.6	T.	T.	4	98.0	57.6	T.	T.
3	316	316		31			31	82	32	68	33	56	197	56.8	.7	.3	34	82.8	57.5	T.	T.	18	90.9	57.6	T.	0.1	6	97.0	57.5	T.	T.
4	316	316		11			11	92	12	82	12	73	189	56.7	.5	.6	12	93.7	57.2	T.	T.	3	98.4	57.4	T.	.2	0	100.0	57.3	T.	T.
5	315	315		15			15	92	16	83	12	74	222	56.6	.5	.5	26	88.3	57.3	T.	0.2	5	97.7	57.4	T.	.2	1	99.6	57.4	T.	0.2
6	316	316		28			28	91	31	80	32	70	174	56.7	.5	.5	30	82.8	57.3	T.	T.	12	93.1	57.5	T.	.1	5	97.1	57.5	T.	T.
7	316	316		12			12	93	13	84	13	76	131	56.7	.5	.4	14	89.3	57.3	T.	0.2	3	97.7	57.4	T.	0.2	2	98.5	57.4	T.	T.
8	316	316		19	9 by 9 mesh	10	19	95	20	87	20	79	179	56.7	.5	.3	21	86.6	57.1	T.	.2	4	97.8	57.4	T.	.1	2	98.9	57.3	T.	T.
9	314	314		25			25	95	29	86	34	75	124	56.7	.5	.3	29	76.6	57.1	T.	.2	7	94.4	57.1	T.	.1	11	91.2	57.3	T.	T.

MACHINE NO. 12—3 TOP AND 2 BOTTOM SCREENS

10[1]	234	234	2 of 4 by 4 mesh and 1 of 4¼ by 4¼ mesh.	13	7 by 7 mesh. 9 by 9 mesh.	22	20	89	23	76	24	65	201	56.9	0.8	0.2	20	90	57.4	T.	T.	2	99	57.7	T.	T.	2	99.0	57.5	T.	T.
						21																																
11[1]	233	233				22	31	91	35	79	37	69	224	56.6	.7	.6	18	92	57.0	0.1	T.	8	96.4	57.6	T.	T.	0	100.0	57.7	T.	T.
						21																																
12[1]	236	236				22	44	91	50	81	55	71	166	56.4	.7	.6	18	89.2	57.4	T.	0.1	2	98.8	57.6	T.	T.	1	99.4	57.6	T.	T.
						21																																
13[1]	236	236				19	46	91	54	80	54	70	114	56.6	.7	.3	8	93	57.2	T.	T.	1	99.1	57.4	T.	T.	1	99.1	57.6	T.	T.
						21																																
14[1]	236	236				22	60	93	63	83	67	73	125	55.2	.5	.8	13	89.6	57.6	T.	T.	4	96.8	57.4	T.	T.	0	100.0	57.3	T.	T.
						21																																
15[1]	234	234				25	56	93	60	84	60	74	169	57.5	.7	.5	14	91.7	57.5	T.	0.1	4	97.6	57.8	T.	T.	3	98.2	58.0	T.	T.
						21																																
16[2]	232	232				19	18	67	23	42	21	26	133	56.8	.8	.1	0	100	57.6	T.	.1	0	100	57.8	T.	T.	0	100.0	57.8	T.	T.
						21																																
17[2]	234	234				19	33	60	36	34	39	18	174	56.7	.6	.4	3	98.3	57.5	T.	T.	1	99.4	57.8	T.	T.	0	100.0	57.9	T.	T.
						21																																
18[2]	233	233				19	56	50	62	24	63	11	331	56.5	.7	.4	2	99.4	57.6	T.	T.	0	100	57.8	T.	T.	0	100.0	57.9	T.	T.
						21																																
19[3]	236	236				19	21	82	25	64	26	51	97	56.7	.8	.4	4	95.9	57.3	T.	T.	0	100	57.6	T.	T.	0	100.0	57.7	T.	T.
						21																																
20[3]	236	236				19	34	78	39	59	39	44	267	56.4	.7	.3	6	97.8	57.6	0.1	T.	0	100	57.7	T.	T.	0	100.0	57.7	T.	T.
						21																																
21[3]	236	236				19	50	76	54	56	52	41	212	56.7	.5	.2	3	98.6	57.6	T.	T.	0	100	57.5	T.	T.	0	100.0	57.7	T.	T.
						21																																

MACHINE NO. 13—2 SCREENS, BOTH ABOVE FAN

22	395	424	13/16	6	8/64	13	8	85	9	73	9	63	400	56.0	0.6	0.9	14	96.5	56.9	T.	T.	1	99.8	57.1	T.	T.	1	99.8	57.0	T.	T.
23	396	422					16	91	20	79	20	72	258	56.1	.7	.6	7	97.3	57.0	T.	T.	7	97.3	57.2	T.	T.	4	98.4	57.2	T.	T.
24	396	424					26	93	29	84	29	75	287	56.4	.5	.5	25	91.3	57.2	T.	0.1	12	95.8	57.1	T.	T.	3	98.9	57.0	T.	T.
25	395	510					7	79	8	65	8	54	270	56.4	.3	.5	0	100	57.6	T.	T.	0	100	57.6	T.	T.	0	100.0	57.9	T.	T.
26	394	510					16	86	20	76	20	67	421	56.4	.7	.6	1	99.8	57.4	T.	T.	0	100	57.2	T.	T.	0	100.0	57.6	T.	T.
27	394	508					27	91	30	81	29	72	210	57.0	.8	.2	4	98.1	57.6	T.	T.	1	99.5	57.7	T.	T.	0	100.0	57.7	T.	T.
28	395	580					9	38	10	22	11	12	436	56.0	.6	.7	0	100	58.0	T.	T.	0	100	58.1	T.	T.	0	100.0	58.1	T.	T.
29	394	576					14	73	21	61	21	50	180	56.1	.9	.7	0	100	57.6	T.	T.	0	100	57.6	T.	T.	0	100.0	57.8	T.	T.
30	394	577					26	87	30	76	31	66	224	56.0	.9	.3	0	100	57.5	T.	T.	0	100	57.5	T.	T.	0	100.0	57.7	T.	T.
31	396	579	13/16	6	7/64	13	9	44	11	28	11	17	354	56.1	.5	.6	0	100	57.9	T.	T.	0	100	58.0	T.	T.	0	100.0	58.0	T.	T.
32	394	580			9/64	13	9	18	12	5			341	56.3	.5	.6	0	100	57.5	T.	T.	0	100	57.8	T.	T.					
33	394	574			7/64	13	16	85	20	74	21	64	188	56.5	.5	.2	0	100	57.1	T.	T.	0	100	57.5	T.	T.	0	100.0	57.6	T.	T.
34	396	576			9/64	13	16	36	19	20	22	10	259	56.5	.6	.2	0	100	57.4	T.	T.	0	100	57.6	T.	T.	0	100.0	57.9	T.	T.
35	396	576			7/64	13	24	91	29	81	30	72	163	56.5	.6	.4	0	100	57.3	T.	T.	0	100	57.4	T.	T.	0	100.0	57.6	T.	T.
36	395	577			9/64	13	27	59	30	38	30	24	252	56.2	.7	.6	1	99.6	57.6	T.	T.	0	100	57.7	T.	T.	0	100.0	57.8	T.	T.

[1] Grade board forward.

[2] Grade board back.

[3] Grade board second hole from back.

Machine no. 11 did a good job of cleaning except for the removal of smut balls in some cases, as is indicated in table 2. A slight change in the design of the machine, possibly increasing the fall through which the wheat is subjected to the air blast, and provision for increasing the air velocity without increasing screen vibration would doubtless improve its performance in removing smut balls. Such changes might, however, increase somewhat the percentage of good grain blown out.

In all but two instances some smut balls were removed each time the wheat was cleaned. For the first cleaning operation from 76.6 to 97.2 percent of the smut balls were removed, depending on adjustments and methods of operation. After the second cleaning operation the percentage of smut balls removed ranged from 90.9 to 98.6, and after the third cleaning from 91.2 to 100, as is shown in table 2. The table shows also that the amount of cleaned wheat was reduced with each cleaning.

Tests were made with machine no. 12 to determine the effect of rate of feeding, angle of lower screen, and position of the grade board on the effectiveness of the cleaner in removing smut balls from wheat. These data show (table 2) that the rate of feed seemed to have little effect on the performance of the machine so far as smut-ball removal was concerned. With the grade board forward, the position recommended for cleaning wheat for market, slightly better results were obtained at 20 and 31 bushels than at 44 bushels per hour capacity. These tests were made with the upper bottom screen forming an angle of 22° and the lower bottom screen forming an angle of 21° with the horizontal. Results of tests made with the machine operated near rated capacity but with variations in the angle of the upper bottom screen indicate slightly better results with the screen set at 19° than at 22° or 25° with the horizontal. In the first cleaning from 89 to 93 percent of the wheat was deposited in the cleaned wheat container with the grade board set forward.

After these tests were completed the grade board was set in the position recommended for cleaning seed wheat, the upper bottom screen was set at 19° with the horizontal and tests made with the machine operating at approximately one-third, two-thirds, and full rated capacity (about 55 bushels per hour). Here again there was no clear indication as to the effect of rate of feed on the performance of the machine in removing smut balls. At a rate of 18 bushels per hour the machine removed all of the smut balls during the first cleaning operation. The first cleaning operation at 33 bushels per hour removed 98.3 percent, and the first cleaning operation at 56 bushels per hour, or full capacity, removed 99.4 percent of the smut balls.

Tests were also made with the grade board set at an intermediate position but near the point recommended for use in cleaning seed wheat. Results of these tests show a higher percentage of cleaned wheat and, in the first cleaning, a slightly lower efficiency in smut-ball removal than when the grade board was set in the extreme rear position.

The position of the grade board, as would naturally be expected, had a considerable effect on the percentage of cleaned wheat obtained. With the grade board set forward, from 89 to 93 percent of the wheat was returned as clean wheat; when it was in the extreme opposite position, from 50 to 67 percent was cleaned.

Machine no. 12 removed a large percentage of the foreign material from the wheat in all cases during the first cleaning operation and had a higher rated capacity than any other of the machines on which observations were made. Tests indicate that this machine will remove all smut balls from seed wheat with 2 or 3 cleaning operations, when adjusted according to manufacturer's instructions for cleaning seed wheat.

Machine no. 13 was operated at approximately one-third, two-thirds, and full rated capacity, with the same rate of screen vibration but at different fan speeds. At a fan speed of about 425 revolutions per minute there was an indication that better results were obtained in smut-ball removal at the lower rates of feeding than at the rated capacity. However, as the rate of feeding was increased the percentage of cleaned wheat obtained also increased. At a fan speed of approximately 510 revolutions per minute, considerably better results were obtained when the machine was operated below rated capacity than at rated capacity. At a fan speed of approximately 575 revolutions per minute the machine removed all smut balls from the wheat at one cleaning operation at approximately one-third, two-thirds, and full rated capacity. However, an increase in the percentage of cleaned wheat in all cases accompanied an increase in rate of feeding.

Tests were also made with this machine to determine the effect of size of openings in the lower screen on the removal of smut balls. These tests were made at the maximum fan speed and, with one exception, all smut balls were removed during the first cleaning operation. The data show, however, that each increase in rate of feed decidedly increased the percentage of wheat deposited in the cleaned-wheat container, with all sizes of screens used. When the machine was operated at about one-third rated capacity with a $\frac{7}{64}$-inch lower screen, approximately 44 per cent of the grain was collected in the cleaned-wheat container, whereas at full capacity, 91 percent was deposited in the cleaned-wheat container. With the $\frac{8}{64}$-inch screen, the range was from 38 to 87 percent, and with the $\frac{9}{64}$-inch screen the range was from only 18 to 89 percent.

To determine the approximate velocity of wind blast to which the grain was subjected in machine no. 13 with the three fan-shaft speeds, anemometer readings were taken at three points across the throat of the air tunnel, the machine running empty. For the slow fan speed the air travel averaged 1,044 feet, for the intermediate fan speed 1,269 feet, and for the fast fan speed 1,409 feet per minute. These figures indicate only the approximate air velocity, as the design of the machine was such as to make impracticable accurate air-velocity determinations at a point where the wheat fell into the wind tunnel.

With high air velocities the rate of feeding from the hopper affects markedly the amount of cleaned wheat obtained. A maximum amount depends on the maintenance of a steady flow of grain, without flooding, over the screen. Resistance to the wind blast offered by the volume of flow, whether the grain be on the screen or falling through the wind blast, determines largely the amount of wheat deposited in the cleaned-wheat container. A dribble of grain fed from the hopper and exposed to maximum wind blast offers little resistance and is largely blown out with the lighter material.

On all of the test runs with machine no. 13, dockage and foreign material other than dockage were practically eliminated in the

cleaned wheat with the first cleaning. On the three runs at lowest fan speed, however, a few smut balls remained in the cleaned wheat with the second and third cleaning, although there was improvement with the successive cleanings. The fact should be noted that smut balls may be found to a considerable extent in cleaned wheat containing but a trace of dockage.

In tests with machine no. 14,[4] experiments were made to determine the effect of fan speed and rate of feed on its performance in removing smut balls from Albit wheat. The wheat weighed 56.3 pounds per bushel before cleaning, was moderately plump, very chalky, and was 3 percent smutty by grade. A $^{12}/_{16}$-inch top or scalping screen and a $^{7}/_{64}$-inch bottom or weed screen were used for all of the tests, and the shaker speed approximated 394 revolutions per minute for all of the tests.

Results of the tests (table 3) show that as the rate of feed was increased the effectiveness of the machine decreased, with few exceptions, for each fan speed. An increase in fan speed was accompanied in most cases by an increase in the percentage of smut balls removed, as well as an increase in the amount of wheat blown out with the light material. The recommended capacity of this machine was 25 bushels per hour in cleaning seed wheat. The test which indicated best results from the standpoint of complete removal of smut balls, high capacity, and a minimum of wheat blown out was with the machine operating at 27 bushels per hour at a fan speed of 649 revolutions per minute. The test which gave the lowest percentage of material blown out with complete removal of smut balls was the one in which the machine was operated at the rate of 7 bushels per hour at a fan speed of 547 revolutions per minute.

TABLE 3.—*Removal of smut-balls from Albit wheat by machine no. 14 as affected by rate of feed and fan speed* [1]

Fan speed (revolutions per minute)	Rate of feed per hour											
	7 bushels			10 bushels			15 bushels			20 bushels		
	Smut-ball removal	Weight per bushel [2]	Material blown out [3]	Smut-ball removal	Weight per bushel [2]	Material blown out [3]	Smut-ball removal	Weight per bushel [2]	Material blown out [3]	Smut-ball removal	Weight per bushel [2]	Material blown out [3]
	Percent	*Pounds*	*Percent*	*Percent*	*Pounds*	*Percent*	*Percent*	*Pounds*	*Percent*	*Percent*	*Pounds*	*Percent*
547	100	56.7	16.7	99.9	56.6	13.3	97.5	56.6	10.0	94.3	56.6	8.3
580	100	56.8	26.7	98.3	56.9	21.7	98.3	56.8	18.3	94.3	56.6	13.3
620	100	57.1	43.3	100.0	57.1	35.0	99.9	57.0	26.7	95.9	57.0	20.0
649	100	57.2	56.7	100.0	57.2	48.3	100.0	57.1	38.3	100.0	56.9	26.7
701 [4]												

[1] Tests made by O. A. Vogel, Bureau of Plant Industry.
[2] Weight per bushel of wheat after cleaning—not "test weight."
[3] Material from scalping and weed screens not weighed.
[4] All grain blown out.

[4] Tests made by O. A. Vogel, Division of Cereal Crops and Diseases, Bureau of Plant Industry, in cooperation with the Washington Agricultural Experiment Station ,Pullman, Wash.

TABLE 3.—*Removal of smut-balls from Albit wheat by machine no. 14 as affected by rate of feed and fan speed*—Continued

Fan speed (revolutions per minute)	Rate of feed per hour											
	27 bushels			43 bushels			52 bushels			60 bushels		
	Smut-ball removal	Weight per bushel [2]	Material blown out [3]	Smut-ball removal	Weight per bushel [2]	Material blown out [3]	Smut-ball removal	Weight per bushel [2]	Material blown out [3]	Smut-ball removal	Weight per bushel [2]	Material blown out [3]
	Per cent	*Pounds*	*Per cent*	*Per cent*	*Pounds*	*Per cent*	*Per cent*	*Pounds*	*Per cent*	*Per cent*	*Pounds*	*Per cent*
547	88.5	56.5	5.0	86.1	56.6	3.3	86.9	56.4	------	90.2	56.4	------
580	94.2	56.7	8.3	95.9	56.5	5.0	91.8	56.5	------	87.7	56.4	------
620	93.4	56.8	13.3	94.3	56.7	8.3	95.9	56.6	------	86.1	56.5	------
649	100.0	56.8	20.0	95.9	56.6	10.0	91.8	56.6	------	85.3	56.5	------
701 [4]	------	------	------	------	------	------	------	------	------	------	------	------

[2] Weight per bushel of wheat after cleaning—not "test weight."
[3] Material from scalping and weed screens not weighed.
[4] All grain blown out.

The results of tests made with machines nos. 13 and 14 indicate that wheat may be exposed to wind blast of sufficient intensity and in such manner as to cause the removal of all smut balls from the smut-infested grain on which experiments were made. An attempt was therefore made to increase the effectiveness of machines nos. 11 and 12 in removing smut balls by increasing the intensity of the air blast. A secondary shaft with cone pulleys was installed on these machines, by means of which the fan might be operated at higher speeds than those indicated in table 2 without excessive screen vibration. Results of tests made under such conditions indicated that changes in the design of the machines would be necessary to effectively utilize air blast in excess of that for which the machine was intended.

For additional information as to the effect of air velocity on the removal of smut balls from wheat, the hopper and fan of one of the cleaners were adjustably mounted in a frame of such design that a wide range of fan speeds and of adjustments in the angle of the fan discharge with reference to the falling grain could be obtained. Tests were made at three different fan speeds, and with the fan discharging horizontally and upward at angles of 30° and 60° against the falling grain. Results of these experiments (table 4) show that, within the experimental limitations, the effectiveness of the cleaners increased with an increase in air velocity and, with some exceptions, decreased with an increase in the angle at which the blast of air was directed against the falling grain.

With air velocities ranging from 1,488 to 1,571 feet per minute, there was little difference in the effectiveness of the machine with the blast striking at 30° and at 60°. At 90°, however, the effectiveness of the blast was much less than at 30° or 60°. With air velocities ranging from 2,209 to 2,248 feet per minute, a change in the angle at which the blast struck the falling wheat had little effect on the performance of the machine in removing smut balls.

TABLE 4.—*Effect of air velocity and angle at which blast strikes falling grain on removal of smut balls*

Air velocity per minute (feet)	Angle of fan discharge with vertical	Smut-ball removal	Cleaned wheat	Air velocity per minute (feet)	Angle of fan discharge with vertical	Smut-ball removal	Cleaned wheat
	Degrees	*Percent*	*Percent*		*Degrees*	*Percent*	*Percent*
1,173	30	88.4	97.7	1,544	90	30.7	97.9
1,209	60	54.2	98.1	2,209	30	94.8	78.3
1,192	90	42.3	99.1	2,234	60	96.6	82.5
1,488	30	94.8	84.9	2,248	90	93.0	92.3
1,571	60	95.3	95.5				

SUMMARY AND CONCLUSIONS

Smut balls are usually lighter and, in some cases, smaller than the kernels of wheat in which they are found. Tests made with both experimental and stock farm-sized cleaners show that wheat may be exposed to air blast of sufficient intensity and in such manner as to blow out all smut balls from the grain. Some smut balls may also be screened out, but screens are not so effective as air blast.

Grain cleaners of the fanning-mill type were found to be more effective in removing smut balls from wheat than other types of cleaners on which tests were made.

A blast of air when directed upward against a stream of falling grain was found to be more effective in removing smut balls, especially at low air velocities, than when striking the stream at right angles.

Generally, the best results in removing smut balls were obtained when the fanning mills were run at considerably less than their rated capacities.

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